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ABSTRACT

For some time there has been a concern in the scientific and academic communities to make science more meaningful to the growing ranks of apparently disenchanted students. This concern is reflected in the development of programs to reassess science curricula on all educational levels. The Thirteen-College Curriculum Program (TCCP) approach to physical science has been to widen the forms of mathematics and its applications to include the natural, though sometime unsophisticated, schematic models developed by students. The theme of this program is student-centered teaching; the program attempts to involve students in principles of each of seven disciplines through first-hand discovery. The students begin with concrete examples and empirically develop from them relevant abstractions and generalizations. The students have tended to become oblivious to some of the artificial barriers between disciplines and have gained a greater appreciation for the structural similarities among them. In this article an example of a class-activity-investigation concerning a conservation law is presented. The investigation concerns the study of a consenvation law and contains basic laws of physics and many aspects of the nature of the scientific method. (Author/PG)

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Analogue Experiences in Physical Science

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Changing Patterns in Physical Science Education

For sometime there has been a concern in the scientific and academic communities to make science more meaningful to the growing ranks of apparently disenchanted students. This concern is very poignantly reflected in the development of programs to reassess and restructure science curricula on all educational levels. Perhaps the greatest challenge in these efforts has been to create a course for students not committed to majoring in science—some of whom might come to major in the subject were it approached in a different fashion. A survey of the physical science text books written on this wave of response shows that by and large there is one point of general agreement: the need to reduce the use of formal mathematics. This is an attempt to remove what is felt to be a major barrier to the non-science student. However, this operation is a delicate one. If too much of the substance of mathematics is removed, what remains may be devoid of the sense of the method of science. Although the non-science student often finds the language of mathematics unnatural, it is an essential part of the language of modern science. It becomes necessary, therefore, to devise a temporary language, usable by students and usable in scientific investigations, and so close the communications gap.

The Thirteen-College Curriculum Program's Response

Our approach to physical science has been to widen the forms of mathematics and its applications to include the natural, though sometimes unsophisticated, schematic models developed by students. Once a student is comfortable in his own approach to science, he is more readily amenable to accepting modification and developing his point of view. We impress upon our students the awareness that there is no one way to view a problem nor any unique description of nature, although some are more economical and elegant than others. There need be no relation between the profundity of a physical concept and the mathematics used to describe it. There are important areas of physics and chemistry where the requisite mathematics are superbly simple. Calculus was unknown to Galileo.

One of the unique features of our course is its setting. It is one of seven courses in the Thirteen-College Curriculum Program. This is an innovative academic program in Liberal Arts for the Freshman and Sophomore years coordinated nationally by the Institute for Services to Education. The theme of the program is student-centered teaching; the program attempts to involve the students in principles of each of seven disciplines through first-hand discovery. The students begin with concrete examples, and develop empirically from them relevant abstractions, and generalizations. This has been an effective method of teaching natural sciences as well as the humanities. The students have been impressively responsive, and even in the earliest stages of the program there have been measureable indications of success.

From a physical scientist's point of view, this program of instruction provides a re-inforcement of the universal utility of the scientific method. In addition, the students have tended to become oblivious to some of the artificial barriers between disciplines and have gained a greater appreciation for the structural similarities among them. Consequently, he then finds it easier to develop inter-disciplinary connections that allow an economy of thought in coordinating diverse information and may more easily generate his own integrated world view. In an attempt to teach "relevant" science in an age of information explosions and planned obsolescence, the method is the message.

In implementing our approach we have found it necessary to utilize a number of teaching techniques and kinds of experiments to deal with varied backgrounds and ability levels of our students. One of these is the frequent use of class-activity-investigations where the entire class participates in an experiment that is coordinated by the teacher. In this way we can establish basic ideas and models of scientific procedure at an early stage in the course without stifling initiative. In this article we present an example of this kind of activity. It concerns the study of a conservation law, and it is so straight-forward that it almost appears simplistic. Yet it contains so many basic laws of physics and reveals so many aspects of the nature of the scientific method that it may be referred to at successive levels of sophistication throughout the course. A complete analysis of this experiment requires use of conservation of energy and momentum as well as a third principle of conservation.

Open-ended Experiments— A Setting Where Ideas Flow

This experiment on a conservation law is designed to involve the student in the discovery process of science as early as possible. It is easily used during the first or second lectures to introduce the scientific method. At the same time it introduces the student to an important physical concept that he may discover with a minimum of mathematical skills; he need only count small integers.

The important features of this experiment are:

1. It has a high probability of success for the student.
2. The student has an opportunity to develop his own mathematical (schematic) language and he begins to get used to drawing pictures to facilitate the intuitive process. An important scientific habit.
3. The experiment is easily extended and leads naturally into several other *basic* physics experiments and motions, viz.,
   (a) conservation of momentum
   (b) conservation of energy
   (c) simple pendulum motion.
4. The student is able to make simple hypotheses and then check his predictions by immediate appeal to simple experimentation.
5. It's just plain fun.

The sole apparatus used for this experiment is one of the commercially made "executive toys" that contain five or more polished steel balls suspended in well-aligned contact. Although most physics apparatus rooms contain versions of this apparatus, they are rarely as friction free as these commercial devices. This is a crucial feature in maintaining the high appeal of the persistant periodic collision patterns.

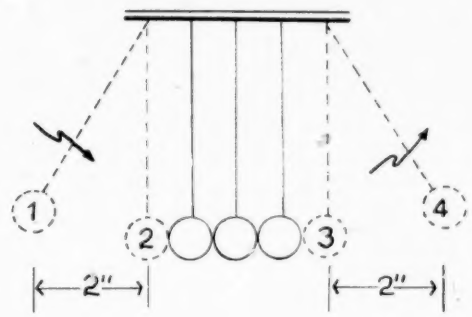
The experiment may be organized so that each small group of approximately four students have one device to study. To begin, ask the students to play with the device in an attempt to try to observe a *pattern* or some *order* in its behavior. In order to make this a constructive kind of playing, ask the students to record a complete description of what they observe. After about 10 minutes organize the class and ask for some descriptions of what they have found, writing some composite class results on the board. Student responses are usually varied at this point, ranging from poetic statements about the rhythmic patterns of motion to statements alleging observation of conservation of energy.

In order to demonstrate the value of a systematic investigation we proceed to the next phase of the experiment. Specific instructions are given for all of the students to follow in performing a well-defined simultaneous experiment. Starting with all of the balls motionless, raise one ball from the end about two inches from the rest and release it, allowing it to swing freely into the others. Next, ask each student to write a complete description of what he observes (repeating the experiment as often as necessary). The description should be sufficiently detailed so that a person who has not seen the experiment may read the description and be able to visualize the *essential* features of the experiment. After this is done a class composite statement is written on the board and general agreement is reached on the accuracy of the description. A shorter version of the statement that results is, "when one ball is lifted 2 inches away from the rest and allowed to swing into the others that are at rest, that ball hits and then remains still while the ball on the opposite end moves up away from the others at a distance of about 2 inches." The teacher may then use this as an opportunity to teach the students the importance of precise and accurate statements to a scientific investigation.

The Development of a Schematic Language

After the class reaches a general agreement on the description of the first experiment, explain to the students that there are a dozen more experiments that we need to perform in order to complete our study. (The *prospect* of having to write twenty more long paragraphs is usually sufficiently threatening that the students are eager to get involved in the next aspect of the experiment.) For the sake of brevity each student is asked to attempt to develop a *non-written*, pictorial language of his own that will adequately describe the experiments to be performed. As a test of the validity of the language ask the students to try to capture schematically important features of the written description of the experiment already performed.

As a response to this there are generally a range of schematic models. Out of the class the teacher might select two students to put their diagrams on the board. The following two representations are typical of such diagrams:



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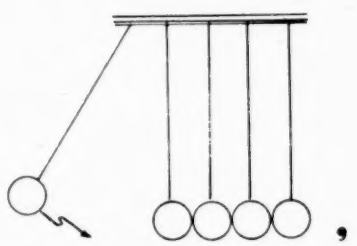

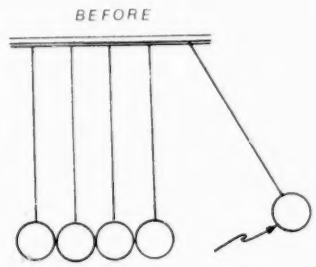

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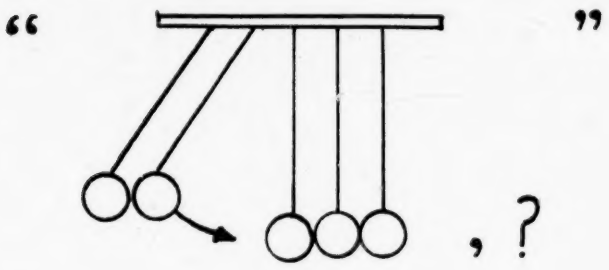
After the two representations are presented on the board it is helpful for the teacher to note similarities and differences between the two schemes. At this point we may then begin to use the language developed by the students to pose questions.

For the next experiment we "ask" the students the following schematic question:



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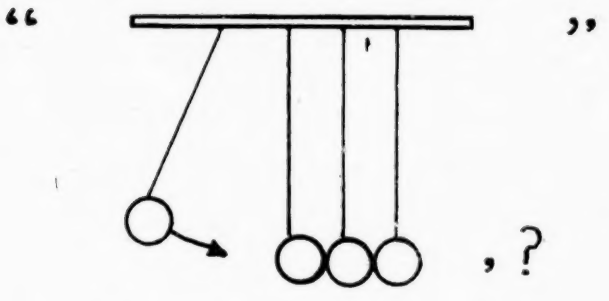
That is, "what will happen if two balls in contact are lifted away from the rest and allowed to swing into the others simultaneously?" We can then select a student to give his written answer on the board, after which we test the students' *hypothesis* by performing the experiment.

In a similar fashion we proceed to ask the additional questions:



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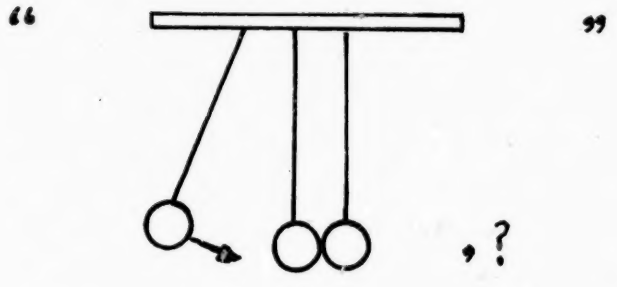

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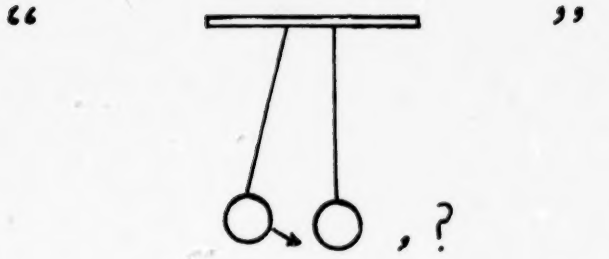

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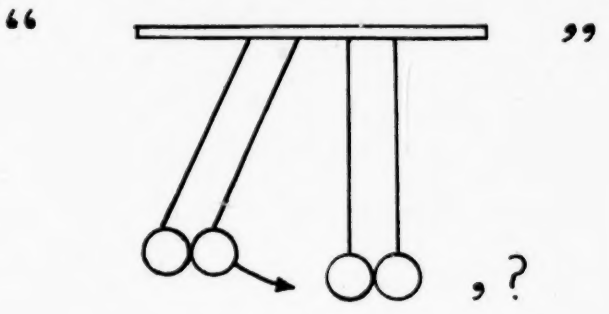
At this point it is appropriate to ask if a pattern is evident. After a series of experiments of this type we can expect the students to give a verbal *generalization* of the fact that "if one ball swings down, one ball will swing up no matter how many balls are in the center." Similarly we would then ask still more questions.



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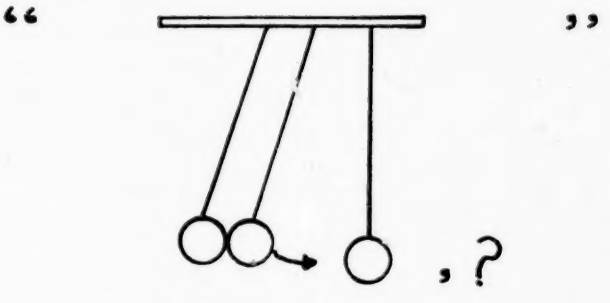

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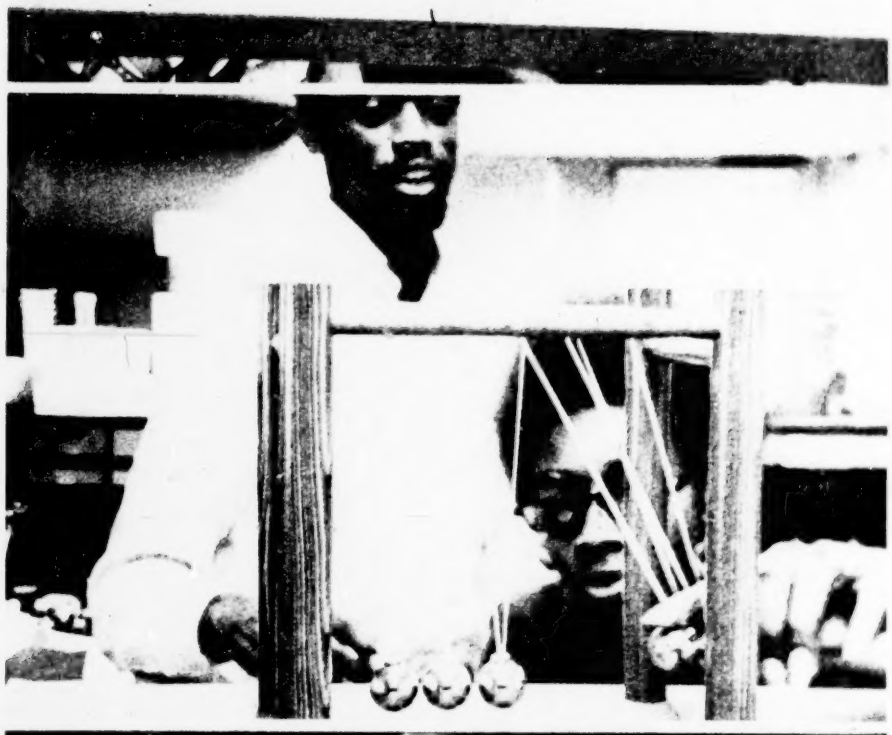
A General Pattern Emerges

After the experiences with the first set of experiments, the students are able to generalize a statement of these new results Ideally, "If two balls drop down, two balls swing up, no matter how many are at rest." At that point we can ask for a generalization for the case when any number of balls swing down.

Next we pose the following more complicated question:

Initial investigations are guarded. What will happen if one ball is pulled back and released?



With new insights, student interest increases. What will happen if two balls are pulled back and released?

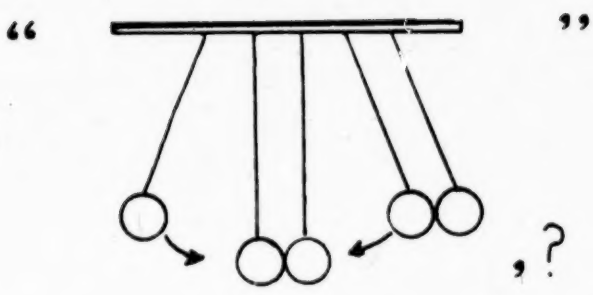
Students design own experiments. What will happen if two balls are released simultaneously from each side?

Students create own descriptive language.

The teacher records results and summarizes. What will happen when three balls are released from one side?

Class involvement grows.

From *Questions Instead of Answers*, a 16mm film by Paul Fremdlich on the 1969 Summer Conference of the Thirteen-College Curriculum Program. Enlargements by James Furlong.



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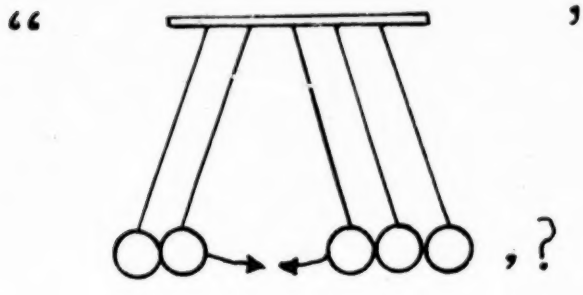
There is usually a controversy on this point as the answer cannot be deduced from the results of the other experiments; thus, we have to appeal to experimentation again.

By this time most students are able to give the correct generalization of this experiment. If not, ask the following questions:



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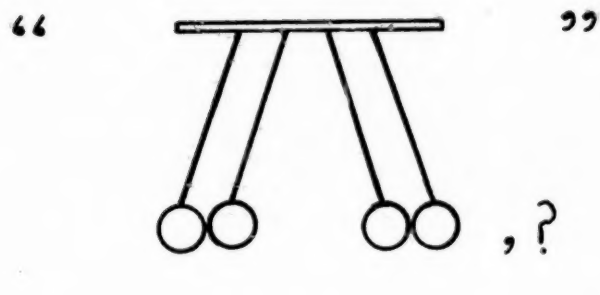

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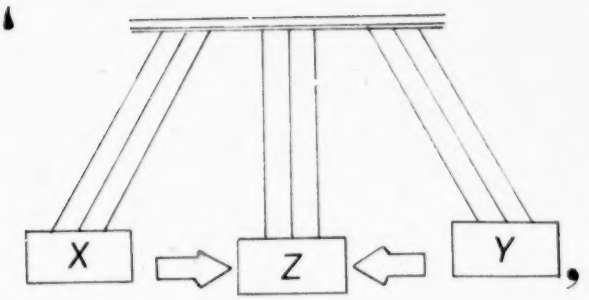
Once the students have arrived at a correct statement of the general principle, it is useful for future reference to have the teacher identify it as a conservation law, and describe it in a modification of their own mathematical language, as follows:



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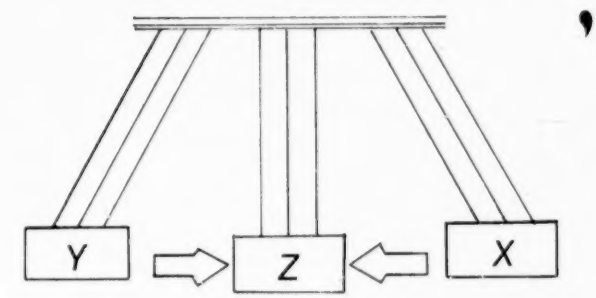

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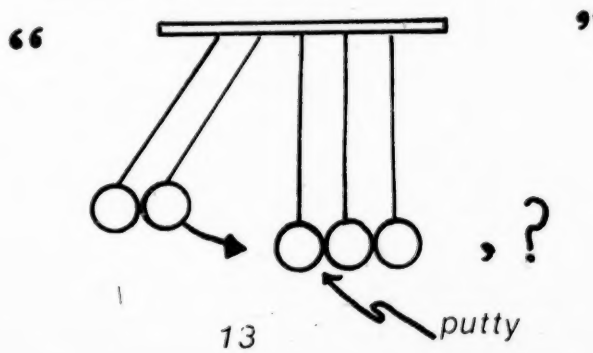
Once this generalized statement has been arrived at, encourage students to apply several more tests to verify it.

Physical Patterns and Universal Laws

As a final step in the experiment a small—almost infinitely small compared to the balls—piece of putty is placed between two balls near the center of the point of contact. It is important to emphasize that the weight of the putty is a negligible contribution to the system. Now we ask a question about this infinitesimally perturbed system.



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The answer is very unsymmetrical and unfamiliar. The question immediately arises, "How can one small piece of putty destroy such a beautifully simple and symmetrical relation? Are the laws of physics so capricious?" These are questions that we are able to answer as we learn to put the laws of physics in a more general form. Students are usually temporarily pacified with the answer, "We will learn that the symmetry and simplicity of behavior is still present; we only have to learn what point of view we need to adopt in order to see it. In this case we need to learn to count another quantity to recognize the more general conservation law, of which our derived law is a special case."

Creative Awareness in Humanities

Part 1. Scope of Course

by Augusta McSwain, Bishop College

and Sara Hollis, Bishop College

"Man and His Creative Awareness," developed by the Institute for Services to Education in conjunction with the Thirteen-College Curriculum Program, is a course which deals with the many aspects of human creativity: music, the visual arts, literature, poetry, drama, architecture, photography, and the film. Traditionally, Humanites courses have dealt almost entirely with Western Civilization and the "Great Works" of that tradition. Certainly this heritage is important to the course, but the ISE- TCCP approach to Humanities is to include not only the major works of Western Civilization, but to explore also the art, music, drama, and folklore in the immediate environment of the students, the contemporary status of all the arts in this country, and the creativity in some non-Western societies, particularly Africa. Emphasis is on the creative process as well as the resultant works of art. The student not only assesses the works of others, but also experiments in his own expression in various media. Thus the student has an opportunity to feel what an artist experiences in creating a painting, writing a play, poem or short story, or making a movie or a series of slides.

Materiels and equipment needed to work in each of these areas are made available. The student is free to work with paints, clay, or paper, movie or still cameras, or tape recorders. The projects are presented in class with the student explaining the process that he went through to complete his project. Students are involved as much as possible in the input in class. They are challenged to do research in areas and to present their results in class and lead discussions about their findings and conclusions.

The subject matter covered is a result of the concerns of both the students and the instructors. It is important that a wide range of subjects be explored—visual arts, drama, literature, music—so that an understanding can be gained of how each one satisfies man's creative urges. These are studied in several cultural areas and historical periods in order to enhance the students' understanding of both the development of art and its interrelationships with culture and society.

The subject matter used, the projects done, the class discussions held, are all means to the desired end of creating in the student a critical judgement of, and enthusiasm for, the creative genius of mankind. It is hoped that this will challenge him to go beyond the classroom with a developed ability to interpret in a sophisticated manner this creativity. And at the same time, this critical judgement should help him to understand and improve his own expression in writing and speaking, as well as perhaps help him to discover in himself a talent in some other form of expression.